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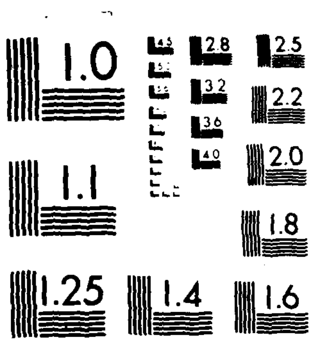

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REPORT BY THE U.S.

General Accounting Office

The Federal Role In Fostering University-Industry Cooperation

Closer links between universities and industry in research and education can enhance technological innovation. However, cooperative arrangements between them are difficult to create and sustain because of differences in missions, values, and rewards.

GAO examined three well-known forms of university-industry collaboration--research parks, cooperative research centers, and industrial extension services--to develop information and guidelines to help policy-makers in designing any new or revised Federal initiatives to stimulate cooperation. Each form of cooperation draws upon different strengths and resources of the participants and produces different outcomes. None is likely to succeed unless the participants possess the relevant strengths and mutual interests.

Federal policy initiatives intended to foster closer links between universities and industry should make financial support contingent upon evidence that the proposed partners are prepared both to reconcile their differences and to address the specific factors essential for success.

UNITED STATES GENERAL ACCOUNTING OFFICE

GAO/PAD-83-22
MAY 26, 1983

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

PROGRAM ANALYSIS DIVISION

B-210894

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
House of Representatives

The Honorable Larry Winn, Jr.
Ranking Minority Member
Committee on Science and Technology
House of Representatives

The Honorable Bob Packwood, Chairman
Committee on Commerce, Science and Transportation
United States Senate

The Honorable Ernest F. Hollings
Ranking Minority Member
Committee on Commerce, Science and Transportation
United States Senate

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In accordance with your requests and subsequent discussions between your staff and our representatives, we have prepared this report on the Federal role in fostering university-industry cooperation.

We are sending copies of this report to appropriate committees of both Houses, Representatives and Senators with particular interest, the Director of the Office of Management and Budget, the Director of the Office of Science and Technology Policy, and the chief officials of the following Federal agencies: the Departments of Agriculture, Commerce, Education, Energy, and Transportation; and the National Science Foundation. We will also make copies available to interested organizations and individuals as appropriate on request.

If we can be of further assistance to you, please do not hesitate to contact us.

Morton A. Myers
Director

REPORT BY THE
UNITED STATES GENERAL
ACCOUNTING OFFICE

THE FEDERAL ROLE IN
FOSTERING UNIVERSITY-
INDUSTRY COOPERATION

D I G E S T

Closer links between universities and industry in research and education can enhance technological innovation, and Federal involvement has been an important factor in fostering university-industry cooperation.

Since World War II, as Federal support of research at universities has greatly expanded, several forms of university-industry cooperation have emerged. Some of these cooperative arrangements involve long-term, deliberately planned institutional commitments. These are difficult to create and sustain because of differences between universities and industry in missions, goals, organization, research objectives, values, and rewards. These differences are generally recognized, and the need to reconcile them without compromising the independence of either institution is widely acknowledged. However, there is little systematic knowledge of how the differences between the two sectors affect cooperative arrangements or how existing arrangements have overcome them.

GAO initiated this review in response to increasing congressional interest in fostering closer links between the two sectors. The report develops information and guidelines to enable policymakers to assess whether new or revised Federal initiatives are needed and how they could be designed to assure that expected outcomes are consonant with policy objectives. The Chairmen and ranking minority members of the House Committee on Science and Technology and the Senate Committee on Commerce, Science, and Transportation expressed special interest in this study and requested a GAO report.

GAO selected three types of university-industry collaboration for study. They were selected because they have been recognized as having a strong potential to contribute to technological innovation, and because they involve long-term institutional commitments to substantially different forms of collaboration. The three types are:

--Research parks; which are composed of clusters of high-technology firms or their research centers located on a site near a research university where industrial occupancy is limited to research-intensive organizations.

--Cooperative research centers; which involve several private firms cooperating with a university in planning, supporting, and evaluating research of mutual interest conducted at the university.

--Industrial extension services, which transfer technology from universities to potential industrial users through designated exchange agents.

For each type, GAO identified

--how the needs and resources of university and industrial participants are joined,

--the types of links and outcomes likely to be enhanced,

--the critical factors involved in creating and sustaining the arrangement, and

--the roles that the Federal Government has played in facilitating its creation and operation.

OUTCOMES ACHIEVED BY UNIVERSITY-INDUSTRY COLLABORATION

University-industry cooperative arrangements often increase communication between scientists and engineers in the two sectors. GAO found that the nature and intensity of communication varies greatly among the different cooperative arrangements, and that the nature of the contributions to innovation most likely to be realized depends on the type of cooperative arrangement.

In the three types of collaboration GAO studied, the most dramatic contribution to innovation appears to be made by research parks. Interaction between the two sectors is enhanced in a variety of ways, such as providing industrial employment of faculty consultants, adjunct faculty appointments for industrial research specialists, sharing of laboratory facilities, part-time employment of graduate students, special graduate courses for industrial employees, and joint research projects and seminars.

Cooperative research centers create new partnerships by bringing both sectors together in jointly-planned research aimed to accelerate the advance and commercial application of technology. Both research parks and cooperative research centers make substantial contributions to improving the initial and continuing education of industrial scientists and engineers.

Industrial extension services are singular in providing assistance to new, low-technology, and fragmented industries. However, in most cases, industrial extension has not had much effect on university research agendas. Both research parks and industrial extension services contribute to regional economic development.

CONDITIONS THAT FOSTER SUCCESSFUL COLLABORATIVE ARRANGEMENTS

GAO found that two kinds of issues are associated with implementing any university-industry arrangement--those that are generic to any form of university-industry collaboration and those that are specific to a particular type of collaboration. Generic issues include the need to reconcile the different objectives, values, attitudes, reward structures, and research agendas of the two sectors; and to locate a source of continuing financial support. An example of a specific issue is the requirement that university and industrial participants in cooperative research centers must agree upon a mutually acceptable research agenda.

Factors essential to resolve the generic issues include

--commitment by both faculty and administrators at a university to the concept of orienting some portion of university research and expertise toward industrial needs and opportunities;

--commitment by participating firms to explore and use the strengths of the university while simultaneously honoring university objectives;

--flexibility in the university to allow policies and organizational developments for interaction with industry which are responsive to industrial objectives but do not compromise the academic mission of the university;

--a strong leader highly respected by both the academic and industrial communities to establish and maintain the partnership;

--matching the physical and human resources, needs, and interests of both university and industrial partners; and

--sustained sources of funding.

Each type of collaborative arrangement draws upon different strengths and resources of university and industrial participants and is not likely to succeed unless universities and firms possessing the relevant strengths and mutual interests are involved. Research parks work best at first-tier research universities where a significant proportion of administrators and faculty favor interaction with industry. Industrial participants most likely to benefit from this arrangement are high-technology firms that depend strongly on technological innovation for their success.

Cooperative research centers require a university with strong departments in areas relevant to the research conducted in the centers. Industrial participation is most successful with medium- to large-sized firms that have adequate in-house research and development capacities to translate research results into commercial technological applications.

Extension services are best performed by a university with a strong commitment to community service and a technological focus aimed at helping local industrial clients.

GOVERNMENT ROLES IN UNIVERSITY/ INDUSTRY COLLABORATION

Federal and State governments have played both direct and indirect roles in creating and sustaining different university/industry arrangements. These roles include supporting research in both sectors, catalyzing the creation of specific arrangements through seed funding, providing long-term financial support for selected arrangements, and providing mission-related project funding to supplement existing arrangements.

In research parks, the Federal role has been predominantly indirect through creating a climate in which industrial firms are more likely to find proximity to a university attractive. Federal support for basic and applied research at universities has

been used by some universities to build research excellence in areas germane to potential industrial technological developments. Continuing Federal support for such research makes proximity to these universities valuable to high-technology firms because the research performed at the university augments the research and development activities of the firms in the park.

In addition to funding university research, the Federal Government has provided support to research parks by awarding contracts to spin-off firms, locating Government research facilities in research parks, and donating land to the host university.

In cooperative research centers, the Federal Government has played a convening and catalytic role by providing seed money to help underwrite experiments with the arrangement. The intent is to help develop new research areas that are of mutual interest to universities and industry, but that are either too peripheral or risky to be sponsored by any single firm.

Unlike the long-term, comprehensive support for an integrated program of education, research, and technology transfer that the Federal Government provides for agricultural extension, the Federal role in industrial extension has been limited to supporting specific mission-related technology transfer projects (e.g., economic development, energy conservation) at universities with existing extension programs. Except for the short-lived State Technical Services program, most of the direct funding for industrial extension has come from State governments.

CONCLUSIONS

The Federal Government has played a significant role in creating and sustaining each type of institutional arrangement by providing

--support of basic and applied research at universities to build excellence in fields of science at the frontiers of industrial technology;

--contract support for research and development (R&D) at spin-off high technology firms;

--seed money to stimulate creation of cooperative R&D centers plus continuing project support by grants and contracts; and

--both seed money and continued funding of extension services.

Financial support alone will not assure success of any of the forms of institutional cooperation. Both the generic and specific critical factors for each type of arrangement must be addressed to assure

--well-defined objectives and expected outcomes of the collaboration;

--matching the resources, needs, and interests of both university and industrial partners; and

--institutional commitments and leadership capable of reconciling the generic differences between universities and industrial partners without incursions on the independence of either.

Federal policy initiatives intended to foster closer links between universities and industry should be designed to

--relate policy objectives to expected outcomes,

--use the most appropriate type of collaborative arrangement, and

--make any targeted financial support contingent upon evidence that the partners proposing the institutional arrangement are prepared to address the generic differences between the two sectors and that the critical factors essential to reconciling them are in place or realizable.

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TABLES

ABBREVIATIONS

CAD/CAM	Computer-aided design/computer-aided manufacturing
CUMIRP	Center of University of Massachusetts/Industry Research on Polymers
ERDIP	Experimental Research and Development Incentiv Program
ESPRA	Empire State Paper Research Association
ESPRI	Empire State Paper Research Institute
GAO	General Accounting Office
IUCRC	Industry/University Cooperative Research Center Program
MIT	Massachusetts Institute of Technology
NSF	National Science Foundation
PENNTAP	Pennsylvania Technical Assistance Program
R&D	Research and Development
RPI	Rennselaer Polytechnic Institute

CHAPTER 1

INTRODUCTION

Closer links between universities and industry in research and education can enhance technological innovation, and Federal involvement has been an important factor in fostering university-industry cooperation. The perceived decline in U.S. innovation and productivity growth during the last decade has led to increasing interest in programs aimed at strengthening university-industry links. Recently, this interest has been heightened by budget constraints on the Federal funding of university research and by industry's tendency to reduce its support for long-term basic research. Interest in the potential benefits of closer university-industry ties has indicated that a more refined understanding of specific types of cooperative arrangements is needed.

INSTITUTIONAL DIFFERENCES/BARRIERS

To realize their full potential, cooperative arrangements between universities and industry must reconcile long-standing differences without compromising their missions and values. Differences are manifest in the research objectives, management philosophies, organizations, and reward structures of the two sectors. For example, universities encourage students and faculty to perform original research. Research results are promptly submitted for publication in peer reviewed journals. Publications produce peer approval and public recognition for the author's contributions to science. Such approval and recognition are integral to the reward structure of academia, constituting an important criterion for faculty promotions.

In contrast, industrial research is aimed primarily at discovering and developing new products and processes, and improving existing ones for competitive advantage in the marketplace. Thus, generally, industrial firms have an interest in maintaining proprietary control over research results; the researcher's rewards derive primarily from his ability to contribute to the firm's technological advantage and potential profitability rather than from peer recognition by the scientific community.

As a result of these differences, university research is sometimes regarded by industrial scientists as "ivory tower," i.e., self-indulgent, with too little application to real world problems; similarly, university researchers sometimes believe that industrial research is inferior in quality because they perceive it as being driven by profit motives rather than scientific merit. These attitudes inhibit interaction, while differences in missions and rewards between the two sectors create practical problems for potential collaborators, involving issues like allocating patent rights, timing research publications, and choosing research objectives.

In addition, barriers to university-industry cooperation may vary substantially depending upon the specific types of universities, industries, and firms involved. Universities, for example, may be either public or private, and they may emphasize research, teaching, and public service missions to widely varying degrees. Industry is similarly diverse in size, products and services provided, and level of investment in research and development (R&D).

BACKGROUND

Federal efforts to foster university-industry cooperation date back to the Morrill Act of 1862, which authorized the creation of land-grant colleges to develop an educational base in agriculture and the mechanical arts. Further legislative initiatives created an integrated program of education, research, and technology transfer to enhance innovation and productivity in the farming industry.

The next major Federal initiative occurred in 1916, when the National Research Council was created to bring Government, industry, and universities together to work cooperatively on researching, developing, and producing military technology. During World War II, university-based centers of excellence were created to focus on microwave radar, nuclear bombs, electronic countermeasures, magnetic mines and degaussing techniques, proximity fuses, etc.

More recent Federal efforts to stimulate university-industry cooperation were initiated in 1972, when President Nixon introduced the New Technology Opportunities Program, which spawned the Experimental Research and Development Incentives Program (ERDIP) at the National Science Foundation (NSF) and the Experimental Technology Incentives Program at the National Bureau of Standards. One of the results of this program was that in 1973, NSF established a program (still in existence) to provide grants to plan and create university-industry cooperative research centers.

Congressional hearings on university-industry relations were held by subcommittees of both the House and Senate in 1979. [1]

1/Subcommittee on Science, Research, and Technology of the House Committee on Science and Technology held hearings on July 31, August 1, and August 2, 1979; and the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation held hearings on June 21, June 27, and November 21, 1979.

These hearings focused on the current status of university-industry relations, on possible congressional roles in facilitating closer cooperation, and on the provisions of the proposed Stevenson-Wydler legislation, which would authorize creating cooperative research and development (R&D) centers at universities. These hearings confirmed the lack of systematic information available on specific types of university-industry arrangements.

The Carter Administration gave the issue of university-industry interaction specific attention in its Domestic Policy Review on Industrial Innovation. The 96th Congress passed the Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480), which authorized the Department of Commerce and the National Science Foundation to create and support centers for industrial technology at universities and nonprofit research organizations. These centers would involve universities and industries in joint research and training ventures. To date, no funds have been appropriated for these centers.

In response to congressional hearings and interest in fostering closer links between the two sectors, we initiated this review to develop information and guidelines that would help policymakers assess whether new or revised Federal initiatives are needed and how they could be designed to assure that expected outcomes are consonant with policy objectives. The Chairman and ranking minority members of the House Committee on Science and Technology and the Senate Committee on Commerce, Science, and Transportation expressed special interest in this study and requested a GAO report.

OBJECTIVES, SCOPE, AND METHODOLOGY

We concentrated on two major policy questions in performing our review: (1) what Federal policy objectives are most likely to be advanced through successfully implementing specific types of university-industry cooperation, and (2) what types of Federal initiatives have fostered specific types of university-industry cooperation. For the first question, we identified the ways in which each of three types of cooperative arrangements joins the needs and resources of university and industrial participants, and the types of links and outcomes that result from the arrangement. For the second question, we identified the critical factors involved in creating and sustaining each type of arrangement, including the role that the Federal Government has played.

The specific objective of this report is to develop sufficient understanding of cooperative arrangements between universities and industry to identify and characterize the different outcomes, requirements, and problems associated with each type.

Three specific criteria were used to select the types of university-industry arrangements we considered. The arrangements selected

--require long-term commitments from both sectors at the institutional level;

--differ significantly in objectives, structure, and operation; and

--have been widely recognized as having a strong potential to contribute to technological innovation.

Using these criteria, we selected the following three types of university-industry arrangements for study: research parks, cooperative research centers, and industrial extension programs. Research parks are composed of clusters of high technology firms or their research centers that are located on or near the campus of a research university. Cooperative research centers involve a number of companies in a formal agreement to sponsor research programs at a university-based center. Extension services transfer technology from a university to potential industrial users through designated exchange agents.

The types of cooperative arrangements we selected are not the only ones worth considering; rather, we chose them because they cover a broad range of alternative approaches and can therefore provide a good starting point for developing policy guidelines for assessing existing Federal initiatives and designing new ones.

We used a case study approach because of the paucity of previous research on specific types of university-industry cooperation. We found no data bases or other information sources available that could be used to determine the specific types of benefits and issues associated with specific types of cooperation. Nor did we find any information on what makes cooperative ventures succeed. Our approach, therefore, was exploratory and limited in the types of questions asked and the number of cases considered. We did not inventory all existing types of cooperative arrangements but restricted our scope to three. We also did not attempt to include all existing examples of these three types, but opted for more in-depth examinations of a small number of cases. We did not systematically evaluate the effectiveness of the arrangements examined nor did we carry out cost/benefit analyses for either university or private firms participating in these cooperative arrangements.

We did not include arrangements between individuals and organizations (e.g., faculty consulting), arrangements where facilities or equipment are shared, or arrangements where the focus is managerial or financial rather than technical Nor did we include indirect approaches to stimulating university-industry interaction such as tax incentives or matching grants.

To develop information on the three types of university-industry arrangements, we conducted 4 in-depth case studies of existing collaborative arrangements and followed these with

briefer examination of 12 additional arrangements. (See tables 1 and 2 for detailed descriptions of each arrangement.)

The case studies

The four examples of university-industry arrangements we selected for in-depth case studies were: the relationship between Stanford University and the Stanford Industrial Park; the cooperative research centers established at the Massachusetts Institute of Technology (the Polymer Processing Program) and at North Carolina State University (the Furniture R&D Applications Institute) and the efforts of the Georgia Institute of Technology (Georgia Tech) to use the extension approach to assist firms in non-agricultural industries.

We chose Stanford because it was the first university-related research park established in the United States and is widely considered the most successful. We selected MIT's Polymer Processing Program because it was one of the first cooperative research centers to be funded by an NSF program, the Industry/University Cooperative Research Center Program (IUCRC), which has served as a prototype for current Government efforts to support the creation of centers for industrial technology.

We chose the Furniture Institute at North Carolina State University because it was regarded as a less successful NSF experiment and because it provided valuable information about the factors which may lead to failure in cooperative centers even when there is Government support.

Georgia Tech's industrial extension program was chosen because it includes a variety of different extension activities directed at nonagricultural clients.

For the in-depth case studies, we conducted 85 open-ended interviews with university administrators, faculty, students, and key representatives from industry management and participating industrial research staff.

Table 1

Case Studies of Existing Collaborative Arrangements

Research Parks	Cooperative Research Centers	Industrial Extension Services
--In-Depth Case Studies--		
Stanford Industrial Park	Massachusetts Institute of Technology's Polymer Processing Program	Georgia Institute of Technology's Industrial Extension Division
	North Carolina State University's Furniture R&D Applications Institute	
--Other Case Studies-		
Research Triangle Park of North Carolina	California Institute of Technology's Silicon Structures Project	Industrial Extension Service of North Carolina State University
University of Utah Research Park	Rensselaer Polytechnic Institute's (RPI) Center for Manufacturing, Productivity and Technology Transfer	Pennsylvania Technical Assistance Program (PENNTAP)
	University-Industry Cooperative Research Program in Computer Graphics and CAD/CAM [a] at RPI	Texas Engineering Extension Service, The Texas A&M University System
	Center of University of Massachusetts/Industry Research on Polymers [b]	
	University of Delaware's Center for Catalytic Science and Technology	
	Ohio State University's Center for Welding Research [b]	
	Empire State Paper Research Institute	

[a]/Computer-aided design and computer-aided manufacturing.

[b]/These were the only two arrangements we did not visit. We interviewed program directors at a conference sponsored by NSF.

Table 2

Description of University-Industry Cases Visited

Type	Name	Description
Research Park	Stanford Industrial Park	--Located on campus of Stanford University. --Predominantly scientific, technical, and research oriented firm with major representation to date in fields of electronics, space, publishing, pharmaceuticals, and chemistry.
	Research Triangle Park of North Carolina	--Formed by Duke University in Durham, the University of North Carolina in Chapel Hill, and North Carolina State University in Raleigh. --Tenants engage in research, development, and scientifically oriented production.
	University of Utah Research Park	--Located on land adjacent to university campus. --Includes high technology firms. --Concentration in medical and earth technologies.
Cooperative Research Centers	Massachusetts Institute of Technology's (MIT) Polymer Processing Program.	--One of three centers initiated by NSF with Federal cost-sharing in 1973; self-supporting since 1979. --Includes 12 noncompeting industrial clients. --Affiliated with MIT's Laboratory for Manufacturing and Productivity.
	North Carolina State University's Furniture R&D Applications Institute	--One of 3 centers initiated by NSF with Federal cost-sharing in 1973; no longer in operation. --Included 6-8 firms in the furniture industry. --Carried out research and technology transfer oriented to needs of the furniture industry. --Free-standing institute housed in furniture manufacturing and management curriculum in the Industrial Engineering Department.

Table 2, continued

Type	Name	Description
	California Institute of Technology's Silicon Structures Project	--Received grant from NSF which has primarily addressed instrumentation needs. --Nine high technology firms support this project. --Located in Cal Tech's Computer Science Department.
	Rensselaer Polytechnic Institute's (RPI) Center for Manufacturing, Productivity and Technology Transfer at RPI	--Receives no Government support. --Membership is drawn from firms in the manufacturing industries. --Interdisciplinary department-level organization reporting to the Dean of the School of Engineering. --Transfers new technology to industry by solving the specific manufacturing problems of each industrial client.
	University-Industry Cooperative Research Program in Computer Graphics and CAD/CAM at RPI	--NSF cooperative centers grant helped to convert the CAD/CAM activity (initiated by RPI) from an industrial associates program to a cooperative center. --Member firms from the aircraft, computer, and graphics industries and firms from other industries. --Located in the School of Engineering. --Focus is on long-range R&D needs of industry in the areas of computer graphics, the use of computer graphics in computer-aided design (CAD), and its relationship with computer-aided manufacturing (CAM).
	University of Delaware's Center for Catalytic Science and Technology	--A project from ERDA (the predecessor of the Department of Energy, DOE) assisted in the creation of this center. The Catalysis Center has received support from DOE, the Environmental Protection Agency, and NSF. --Has 23 industrial sponsors from the oil and chemical industries. --Located in the Department of Chemical Engineering with participation by members of the Chemistry Department.

Table 2, continued

Type	Name	Description
		--Performs fundamental research in catalysis which underpins the technology needed to address problems of energy and raw materials utilization.
	Empire State Paper Research Institute (ESPRI), State University of New York's College of Environmental Science and Forestry at Syracuse	--Established in 1958 by Empire State Paper Research Association (ESPRA). Began as the ESPRA research group in 1946. --Serves 78 corporations in 15 countries which constitute the entire membership of ESPRA. --Located in College of Environmental Science and Forestry, and is closely linked with the College's Department of Paper Science and Engineering. --Focuses on fundamental research oriented to the production of pulp and paper.
Industrial Extension Services	Georgia Institute of Technology's Industrial Extension Division	--Located in the university's Engineering Experiment Laboratory. --Provides service through statewide system of 8 field offices. --Oriented to serve small manufacturing firms.
	Industrial Extension Service of North Carolina State University	--Extension agents located in university departments. --Provides field services, continuing education, and services through departmental units to a variety of industries.
	Pennsylvania Technical Assistance Program (PENNTAP)	--Created with Federal cost-sharing. --Extension agents located in university departments. --Oriented primarily to disseminate data and information to a variety of industries.
	Texas Engineering Extension Service	--Predominantly educational program. --Aimed at developing occupational training programs in a number of different fields.

CHAPTER 2

THE RESEARCH PARK APPROACH

Research parks are composed of clusters of firms located on a site near a research university in which industrial occupancy is restricted to research-intensive organizations. Interest in the potential benefits of locating research-intensive firms near high-quality research universities was sparked in the late 1950s as a result of the dramatic successes achieved by innovative new firms which were started in the areas surrounding the Massachusetts Institute of Technology (MIT) and Stanford University. The firms located near these universities often originated as spin-offs of university research, to exploit state-of-the-art developments in science and engineering.

The success of Stanford's research park in contributing to the welfare of the university and to the economic development of the region led to a number of efforts to replicate the research park approach at other universities. A 1980 report prepared by Ohio State University found that 27 university-related research parks have been started since 1951, the year that the Stanford park was opened. Not all of these have succeeded, however. The report found that of the 27, 6 had clearly succeeded, 16 had failed, and 5 were "in-between."

The three parks we selected are not a representative sample since all of them have experienced some success. Two of our three cases--Stanford Industrial Park and the North Carolina Research Triangle Park--are generally regarded as successes while the University of Utah Park is characterized in the Ohio State Study as being "in-between." In our analysis, we sought to identify the specific attributes that contributed to the success of the parks we studied. Research parks can be termed successful when they attract a large number of industrial firms. However, our major criterion for success is a research park's capacity to stimulate interaction between universities and industries in ways that enhance technological innovation.

In this chapter we describe the ways research parks work to promote university-industry interaction and delineate the types of research cooperation in the parks we examined; we discuss the contributions that research parks can make to R&D in the United States; we identify the factors that we found to be critical in achieving successful university-industry cooperation in research parks; and we discuss the roles that the Federal Government has played in fostering successful research parks.

HOW RESEARCH PARKS WORK TO PROMOTE UNIVERSITY-INDUSTRY INTERACTION

Academic scientific research has traditionally been somewhat segregated from industrial research activity in the United States because of differences in attitudes and research objectives. In this section, we describe how locating research parks near universities can lead to increased levels of interaction and research cooperation between researchers in the two sectors.

Increased interaction

First, research parks break down spatial barriers between university and industry researchers, making it convenient for them to interact more frequently and more intensely. Frequent and effective exchanges of information increase understanding between the sectors and make mutual assistance more likely. Scientists can gain more familiarity with the problems and perspectives of their counterparts in the other sector. This broadens their understanding of the possible implications of their own work and allows greater ongoing access to new developments as they arise.

Second, university and industry personnel are more likely to take advantage of each other's existing programs and resources in a research park setting. Industrial scientists in research parks frequently attend university lectures and seminars. They are likely to take advantage of university adjunct professorship appointments and often serve as visiting lecturers or as members of dissertation committees. Firms located in research parks are often active participants in university industrial-affiliate and continuing education programs. Similarly, university researchers and students attend lectures and seminars at firms located in the park, and faculty members take advantage of increased opportunities for consulting arrangements. Researchers from both sectors take advantage of the wider range of facilities present in research parks, such as libraries and special-purpose laboratory equipment.

Third, research parks provide opportunities for creating new cooperative programs. We found a number of these programs in our survey. For example, programs for sharing laboratory facilities were developed in all of the parks we visited, and most had instituted personnel exchange programs. Closed-circuit television transmission of continuing education programs has been established at Stanford to address the needs of research park residents; similar capabilities are currently being developed in the Research Triangle Park of North Carolina.

Research collaboration

Research parks are most successful at fostering joint university-industry research collaboration in areas on the frontiers of science, especially those that are seen as having great commercial promise. Collaboration takes a number of different forms and ranges across the R&D spectrum, including basic research, applied research, and development. We even found one instance of product testing.

Companies that find research parks attractive and economically feasible are often those whose competitiveness and growth are determined by their innovative research and for whom decisions about the location of either the entire firm or a research facility are not heavily influenced by other factors (e.g., proximity to markets, raw materials, or unskilled labor). For these firms, gaining early access to new developments in university research is a key to their continued success. They, therefore, are most interested in locating near universities that are on the research frontiers of the fields in which they have primary interest. In these circumstances, the mutual interests of university and industry researchers tend to be concentrated in state-of-the-art research.

Collaboration in basic research took place in all of the research parks that we visited, most often carried out in university laboratories but also in the laboratories of industries and research institutes. Typically, collaboration involved either industry funding of specific basic research projects or industry monitoring of basic research developments on an ongoing basis.

Applied research conducted in university laboratories and research institutes often involves university faculty and industrial researchers cooperating in defining research needs and design, as well as in performance. Because of their proximity to the university, firms located in the park are able to use university consultants continually in planning, directing, designing and evaluating research conducted in industrial laboratories.

Development activities in research parks are concentrated in industrial laboratories because of the firms' concern about the proprietary nature of results and the desire to integrate engineering with the design of manufacturing prototypes. There are two types of university involvement in industrial development: faculty consulting, and industrial recruitment of students with research experience and aptitudes related to their development activities. Proximity to the university allows industry to identify students with knowledge and expertise in areas relevant to their needs and to cultivate relationships with them early in the recruitment process.

We saw one example of the use of the university as a neutral testing site for new industrial products. Burroughs-Wellcome

Company, a resident of Research Triangle Park, produces pharmaceuticals and contracts with eminent medical schools to conduct clinical trials on new products. Particularly when the clinical trial is a critical one, Burroughs-Wellcome finds it convenient to have the trial conducted close to their offices. Therefore, the company frequently contracts with the medical schools of Duke University and the University of North Carolina for such trials.

MAJOR OUTCOMES THAT CAN BE EXPECTED FROM RESEARCH PARKS

Increased interaction between universities and industry in research parks helps contribute to R&D in the United States and the regions in which they are located in the following ways: increasing the availability of sophisticated facilities, equipment and expertise to scientists and engineers in industry and academia; facilitating early recognition of research breakthroughs that make new products and processes possible; improving preparation of science and engineering students for industrial careers; continuing education of industrial researchers; and enhancing regional and local economic development.

Increased availability of expertise and facilities

Many interviewees reported that one of the most pervasive, although difficult to measure, outcomes of the research park arrangement is its effect on the efficiency and creativity of research and development. As the opportunities for contact with well-informed, productive, creative scientists and engineers increases, the likelihood of each researcher's thinking and performance being stimulated and sharpened also increases. We found numerous examples where access to university research and researchers were reported to have influenced industrial R&D and similar cases where university research was influenced by industrial researchers and technological developments. But many of these examples of mutual stimulation across university-industry lines cannot be easily traced; the effects must be assumed to be a probable result from the increased communication and access made possible by successful park arrangements.

Facilitating early recognition of research breakthroughs

The increased communication between scientists and engineers described above stimulates innovation not only by influencing research but also by improving the flow of research results across institutional boundaries. In addition, research parks contribute to innovation by facilitating the licensing of university research discoveries, and providing an environment conducive to the development of spin-off firms.

The patenting and licensing of new inventions is complex and time-consuming, deterring many university professors from pursuing potential inventions to commercialization. All of the universities we examined had technology licensing programs to perform this function. In these programs, personnel are assigned to evaluate inventions for their potential for success, carry out the patenting process, and promote and arrange licensing agreements with industry. One problem with most technology licensing offices is that the inventor often cannot be personally involved in demonstrating the merits of his idea to industry. The increased access to industry in research parks facilitates licensing by allowing the inventor to participate in promoting the invention to park residents.

Research parks are excellent spawning places for spin-off companies, because they provide the business and technical expertise necessary to support promising ventures. Spin-off companies are usually started by individuals who draw heavily on scientific and technical knowledge used in their previous employment, whether it was with an industrial firm, a university, a Government research agency, or a nonprofit laboratory.

Spin-off firms can originate with university or industrial researchers in a research park, depending upon the stage of research progress in an area. Firms are more likely to spin off from university research in areas where commercial application is just beginning. As the number of firms exploiting a given body of knowledge increases, spin-offs are increasingly likely to be offshoots of industrial R&D rather than university research. In the Stanford University Industrial Park, for example, there were two distinct generations of spin-off companies. The first generation (companies such as Hewlett-Packard, Watkins-Johnson, and Varian) are spin-offs of research originally conducted at the university. The second generation consists primarily of companies that have spun off from other high-technology firms.

Spin-off companies tend to stimulate additional spin-offs because they provide a success model for potential entrepreneurs. This encouragement of risk-taking has been an important aspect of the University of Utah Research Park. The Utah park includes among its occupants two organizations that exist primarily to encourage entrepreneurship. One, the University of Utah Innovation Center, is funded by NSF to help entrepreneurs begin new businesses by providing them with access to university facilities and expertise. The other, Resource Enterprises, Inc., has as its primary objective enhancing its parent company's (Terra-Tek) diversification and growth by providing managerial, accounting, legal, and financial assistance to entrepreneurs interested in translating their ideas into new subsidiaries for Terra-Tek.

Improved education for students
and industrial researchers

Research parks provide numerous opportunities for upgrading the education of science and engineering students. Graduate students in many disciplines work for participating corporations as research assistants and consultants year-round. Participation in industrial research increases student familiarity with industrial interests and procedures and sensitizes students and faculty to the challenges of industrial work. Firms in all of the research parks that we visited reported using students to aid in research tasks.

Another common practice of industrial firms in research parks is sharing rare or expensive instruments and equipment with university faculty and students. This enables students to undertake projects that they would otherwise be unable to attempt, thereby adding an additional dimension to their research and education.

Continuing education opportunities for industrial scientists and engineers are also enhanced. Because they work in companies that depend on exploiting developments in research for their success, industrial researchers need to constantly update their scientific and technical knowledge. Continuing education programs provide the instruction needed to keep up with new developments. Universities in two of the research parks we examined provide continuing education programs for the scientists and engineers employed by the firms in their park.

Stimulation of regional economic development

Each of the parks we visited has had a positive effect on the local economy. In North Carolina and Utah, the desire for accelerated economic development led directly to using research parks affiliated with State universities to attract new high technology firms. At Stanford, an important motivation for the development of the research park was concern over the "brain drain" of Stanford-trained scientists and engineers to large east coast companies. Many technology-intensive firms, both large and small, have been attracted to the Silicon Valley region surrounding the park to take advantage of the university and the industrial cooperative education program.

FACTORS NECESSARY FOR SUCCESSFUL
UNIVERSITY-INDUSTRY INTERACTION

Physical proximity of a university to private firms is not sufficient to assure that a research park will produce the results described in the previous section. We found that two important factors increase the probability that a park will make

such contributions. Faculty and administrators must be committed to having an ongoing relationship with industry be an integral part of the university's mission, and the strengths of the university and the interests of park tenants must be well-matched.

Integration into the university's mission

Developing a strong and positive relationship between universities and private firms requires more than a university decision to sponsor a research park. University administrators must find ways to make interaction with industry an accepted part of programs of research and education aimed at achieving academic excellence. Dr. Terman of Stanford has noted that:

> "If a university is to become an important factor in industrial development, a significant number of faculty members must develop and maintain personal acquaintances with key people in local industry and...[help] local industry become acquainted with the university. These faculty...must have a real perceptive interest in the problems of industries so that some degree of involvement with industry is a pleasure, not an assigned chore. It is also necessary to educate those segments of the local industry that are oriented toward an advancing technology, to the fact that the university can be a great value to them, and that it is to their advantage to make an effort to learn what the resources of the university are and how they can be used."

To develop and sustain successful collaboration, the university must maintain a fragile balance between policies that reward the active pursuit of relationships with industry and commitment to high quality academic performance. In the research parks that we visited, we found two approaches to the problem of integrating ongoing interaction with industry into the traditional mission and objectives of the university. The first was to develop university policies that incorporated interaction with industry into a larger plan for upgrading and sustaining the academic excellence of the university. The second approach was to make involvement in the research park a part of the university's public service mission.

Stanford is unique among the universities we examined in its success at using both of these approaches. For this reason, several schools have used it as a model. The success of the Stanford University Industrial Park hinges on the university's ability to combine encouragement of industrial interaction and community service with a continuing commitment to the highest standards of academic excellence.

Stanford used long-term planning to ensure that its attempted blending of academic and industrial priorities would succeed. In 1944, under the leadership of Dr. Frederick Terman, who served as both Dean of Engineering and Provost of the university during the postwar period and who foresaw the increase of Federal support for university research that was to occur in the 1950s and 1960s, the university developed a 20-year plan to use this support to build Stanford from a good regional university into a nationally prominent research institution. Part of the plan involved making Stanford a nucleus for industrial R&D to provide local jobs for Stanford graduates and to join the university with industry in contributing to the economic growth of the region. University resources were concentrated on attracting to Stanford the top researchers in disciplinary sub-specialities selected for their potential to make contributions to "growth industries."

To increase faculty interest in interacting with industry, the university also instituted a reward structure that provided strong incentives for such interaction and gave high priority to admitting firms into the research park that were likely to contribute to the university's academic objectives. Most important, the university's plan was explicitly based on a conception of ongoing university-industry cooperation as complementing, rather than competing with, traditional university commitments to academic excellence and public service.

In contrast to the Stanford approach, the parks we studied at North Carolina and Utah were developed largely as an outgrowth of university commitment to a public service mission. In both cases, State universities became involved at least partly as a result of State governments conceiving universities as regional resources that could be used to attract new, high-technology industries. In neither case was much effort devoted to integrating industrial interaction with the academic missions of participating schools--ongoing comprehensive plans like Stanford's were not developed.

The absence of policies that explicitly connect the academic program of the university to the research parks has led to these two parks experiencing more limited success than Stanford in stimulating university-industry interaction. North Carolina's Research Triangle Park has been somewhat more successful in this regard than has Utah. The key to this success has been the strong commitment of one of the participating schools to public service. North Carolina State University (N.C. State) has been substantially more involved in interaction with park residents than has Duke or the University of North Carolina. N.C. State is the State system's engineering school and consequently has much to offer the participating firms. As a land-grant college, the university has a history of commitment to both academic excellence and the application of knowledge to practical problems outside the university. N.C. State has led the way in shaping

the character of university-industry relations in Research Triangle Park, which is strongest in education and consulting.

By contrast, Duke, which is a traditional, private, academically oriented institution, has not established significant interaction with industry because of faculty indifference. Duke's Dean of Research noted that his school has one of the best genetics departments in the United States, yet it has almost no contact with industry. He also noted that Duke is currently attempting to increase its industrial relationships by building administrative structures to work with industry, using Stanford as its model.

The University of Utah has attempted to develop its research park along the lines laid out by Stanford but has achieved only limited success. One factor that caused difficulty was the sudden way in which the university committed itself to a research park (see p. 20). Initial interest in developing the park was aroused by the availability of surplus Federal land that bordered the university. Action to secure the land and develop the park had to be carried out quickly, and there was little time for preparation. We found, consequently, that interaction between park tenants and the University of Utah is concentrated in exchanges of personnel through adjunct professorships and faculty consulting, equipment sharing, and continuing education; participation in joint research programs was not extensive. The university has apparently not succeeded in encouraging interaction from the viewpoint of either academic interest or public service.

Matching university strengths and industrial objectives

Effective university-industry interaction is more likely to occur when university strengths are well-matched to industrial needs. The shared interests that we found in the parks we visited varied from firms that moved to a park because of a strong interest in the work of a single researcher to firms that had no specific substantive interest but were anxious to move to an area that had a strong academic ambience to meet the needs of their professional employees. Many companies were attracted by a single department of a university. The electrical engineering department at Stanford, the medical school at the University of North Carolina, and the bioengineering department at the University of Utah were all mentioned by industrial representatives as factors in their firms' decisions to relocate. Some firms at Stanford were attracted by the overall quality of the university. A number of the firms moved to Research Triangle Park because of the quality of life in the area.

We wish to reemphasize that the existence of an excellent academic department close by an industrial firm that has similar research interests is not sufficient for an active collaborative relationship. The university must work at making a fruitful relationship a reality.

THE FEDERAL GOVERNMENT'S ROLE

The Federal Government has played two influential roles in creating and maintaining successful university-industry interaction in research parks. It has provided funding for basic and applied research that has helped universities to develop their research capacity, thus attracting industrial firms to the parks, and helping to support spin-off firms; and it has sometimes helped research parks form and grow by providing other types of support, such as land or moving Federal research installations to parks.

Funding basic and applied research

The most important role that the Federal Government has played in stimulating university-industry relations in research parks is indirect. By taking upon itself the stewardship of basic research in the United States and increasing support of applied mission-oriented research, the Government has helped develop a research capacity in some universities that has made them a magnet for high-technology industries.

This infusion of Government money into university research has helped universities in several ways. First, it has underwritten the development of academic departments that have produced students and research results of direct interest to industry. We found a number of instances where companies have moved near universities specifically to have ongoing access to research activities, students, and faculty in a particular field of science. Second, this Federal support has led to the creation of new firms founded by university researchers interested in pursuing commercial applications of their own work. These firms often secured considerable financial support in their early years from Government R&D and procurement contracts. Third, the availability of Government research support protects the independence of university researchers and allows them to pursue only those industrially-sponsored research opportunities that also contribute to scientific progress in their fields of expertise.

Other types of support

While the Federal Government has never specifically attempted to initiate a research park, we identified several Federal actions that have contributed to creating and maintaining specific parks. These include moving Government facilities to research parks, providing Federal land for parks, and creating a federally funded innovation center in a research park.

Moving Federal facilities to research parks helps bring together researchers in specialized fields who can share expertise, facilities, and ideas that enhance innovation. The Environmental Protection Agency (EPA), for example, is the largest single employer in North Carolina's Research Triangle Park. Firms there, as well as the universities associated with it, interact frequently with the EPA research facility. Federal research organizations also can increase the number of park tenants by drawing firms that do work relevant to the particular agency's mission.

The land for the University of Utah Research Park was acquired from the Federal Government under the provisions of the Public Purposes and Recreation Act, which allows surplus lands to be deeded to States for public purposes. In this case, the land was part of a former fort that had been declared surplus by the Secretary of Defense. As an expanding university which had already acquired much land, the university could not have justified acquiring additional land under normal circumstances. However, since the university was able to adopt a plan to use the land as a research park, it was deeded to the State by the Department of the Interior, which audits its use on a semiannual basis. Since the availability of land near a university is crucial in developing a research park, the Government's role in this case was critical. However, the circumstances were unique and such Government assistance would be unlikely in most cases.

NSF has played a unique role at the University of Utah Research Park through its support of the Utah Innovation Center (UIC). UIC was organized to help entrepreneurs set up high-technology companies. The center provides would-be entrepreneurs with start-up funds, laboratory and work space, and access to facilities and personnel in return for equity in the companies it helps to create. Formal university course work is used as a part of the program to prepare entrepreneurs to run their own businesses. The courses are particularly important in instructing engineers how to prepare financial statements and carry out long-term financial planning.

CHAPTER 3

COOPERATIVE RESEARCH CENTERS

INTRODUCTION

The cooperative research center approach to university-industry cooperation joins a number of firms with a university in a long-term research program in an area of common interest to the participants. The approach differs from many other types of university research centers and from most university-industry research consortia because, in cooperative centers, industrial sponsors play an active role in making policy, planning research projects, and overseeing the implementation and evaluation of research conducted at the university.

Cooperative research centers have received considerable Government attention during the last decade as promising mechanisms for bringing together university and industrial resources in research areas that fall between academic disciplinary research and the specific areas of applied research pursued by individual firms. NSF has been supporting cooperative research centers through its Industry-University Cooperative Research Centers Program (IUCRC) since 1973. More recently, the Congress passed the Stevenson-Wydler Technology Innovation Act (P.L. 96-480), which includes provisions authorizing the Department of Commerce and NSF to create centers for industrial technology to be affiliated with universities or other nonprofit organizations and aimed at stimulating industrial innovation.

We performed two in-depth case studies of cooperative research centers and examined seven additional centers in less detail. The in-depth studies--both the Polymer Processing Center at MIT and the Furniture R&D Applications Institute at North Carolina State--were initially funded by IUCRC in 1973. Of the seven additional cases, three centers more recently received funding through the IUCRC, three received some Federal support but not from IUCRC, and one received no institutional support from the Federal Government.

In this chapter, we describe how cooperative research centers work, what they produce, some factors critical to their success, and the roles Government has played in fostering their success.

HOW COOPERATIVE RESEARCH CENTERS WORK

The purpose of the cooperative research center is to provide an opportunity for sponsoring firms to pool their resources to support research in an area of shared but limited interest. Locating the center at a university provides additional benefits in that individual industrial sponsors do not have to acquire research facilities or equipment and they may take advantage of the

relatively inexpensive labor of student researchers. The university derives benefits because the center provides research support for students and faculty and also provides valuable training for students planning to pursue industrial careers.

All of the centers that we examined were first proposed at universities; promoters of the idea then sought support among university faculty and administrators and among industrial representatives. The centers generally were structured to include industrial advisory panels to help formulate center policies, research agendas, and procedures; a director who was responsible for the day-to-day operation of the center and who served as liaison between university and industrial participants; and students and faculty who had primary responsibility for designing and carrying out research projects. Most of the centers had some type of regular reporting procedures in which the progress and results of research were communicated to industrial sponsors.

The primary activity of cooperative centers is research. We found that the research performed in cooperative centers fills a gap in the overall U.S. research agenda that probably would not be filled by more conventional research arrangements. Many of the centers we visited were devoted to technologies (e.g., welding, automated batch manufacturing, and the design of silicon chips) that had been previously identified as being of substantial significance to one or a number of U.S. industries but which were not likely to become the focus of individual industrial research laboratories.

In the centers we visited, we found that the research performed was predominantly applied, ranged from being oriented to the needs or interests of an entire industry or several industries to projects focused on the specific concerns of a single sponsoring firm, and was often a hybrid of industrial and academic approaches to the design and reporting of research.

We found that most of the research carried out in cooperative centers was directed toward the practical application of knowledge and, therefore, falls broadly under applied research. However, the work varies substantially both within a given center and among centers, ranging from basic research "directed" at disciplinary areas having high potential for industrial applications to developing "closed system" or "turn-key" technologies that are ready for industrial use. Some centers, e.g., the University of Delaware Catalysis Center, engage primarily in focused fundamental research. Research is driven primarily by a desire to explore the phenomenon of catalysis, but areas of research are selected which can be exploited by industry. On the other hand, centers such as the Renssalaer Polytechnic Institute (RPI) Center for Manufacturing produce technologies that can be transferred directly to the manufacturing firms.

As they mature, centers often change the balance of basic and applied research. Some center directors told us that at first they performed applied research specifically tailored to the problems of their sponsors in order to demonstrate their usefulness to industry and thereby attract "repeat business." The Empire State Paper Research Institute (ESPRI), for example, began with a very short-term, practical problem which faced its first group of member firms. The research program later expanded its scope first to address all aspects of wood pulp and later, as the composition of its industrial membership expanded and diversified, into fundamental, long-range research for the paper industry.

How cooperative centers orient research has a number of implications for center participants. The more basic the research orientation, the greater the reliance on the sponsor's capacity to translate the research conducted at the center into specific applications. Centers that strongly emphasize applied research are likely to be located in engineering schools or associated with university departments with a similar emphasis, while centers that focus on basic research are more likely to be associated with more traditional, discipline-oriented departments.

All the centers we examined were interested in achieving generically useful expertise in their areas of research specialization, but went about it in different ways. Some centers selected all of their research projects on the basis of each project's general relevance to the research needs of a number of sponsoring firms. Others tailored projects to the specific interests of each industrial sponsor, arguing that the shared knowledge and experience gained by executing several such projects increases capability in the area. Several factors influenced this choice of strategy, including the number of sponsoring firms in the center, the cost of joining the center, and the nature of the technological area in question.

Cooperative research centers are distinguished from other university research organizations by their hybrid status; they are crosses between university and industrial research operations that often combine the research practices of both sectors. How the research process is organized at many centers provides a marked contrast with more traditional university research organizations. At these centers, project proposals define measurable objectives (goals) and establish observable milestones within a set timetable.

Also, results of research performed at centers is often consciously packaged for industrial consumption. For example, the Catalysis Center at the University of Delaware presents research results to member firms in a format that "resembles the internal progress reports of a company," and avoids the "typical academic trap of obscuring...details."

UNIVERSITY-INDUSTRY INTERACTION IN COOPERATIVE CENTERS

Cooperative research centers can increase the level of university-industry interaction in two areas--research and education--in improving coordination of jointly planned university and industry research, producing generic research that contributes to industrial innovation and productivity of sponsors, and improving education and training of scientists and engineers oriented toward industrial careers.

Improved research coordination

Cooperative centers provide opportunities for university-industry interaction at each stage of the research process, i.e., in the planning of a research program, the design and implementation of research projects, and in the transfer of research findings to industry for development.

The centers enable university and industrial researchers to coordinate their research agendas, which can increase the pool of ideas available, and can also increase the probability that university research will produce findings relevant to industry.

Cooperative centers provide opportunities for increased communication and coordination between university and industry researchers, and between researchers within each sector. They are viewed by some as mechanisms for increasing communication between firms and thereby initiating discussions of problem areas in industrial processes that could benefit from innovation. Those at ESPRI, for example, believe that meetings between papermakers and machine-builders (two types of firms that play different roles in papermaking) can upgrade the quality of the papermaking process. Instances of increased interaction within participating firms and across departments of participating universities were also reported.

Research that contributes to industrial innovation and productivity

Cooperative research centers can contribute significantly to industrial innovation and productivity by conducting research that increases industrial understanding of the scientific basis of technology. Center researchers described industrial processes such as polymer processing and catalytic technology as being based on "black arts" rather than on a systematic understanding of the underlying characteristics and properties of materials and processes. For example, faculty members at Cal Tech's silicon structures project said that they decided to focus on the design of silicon chips because "industry had an engineering perspective in this area but no research understanding."

Cooperative centers also contribute to innovation by providing industry with early access to university research. Ability to take advantage of this early access varies with the sponsoring firm's research sophistication. For all firms, early access "shorten(s) the gestation period necessary before university ideas reach the factory floor." A representative of the Empire State Paper Research Association (ESPRA), the organization which administers ESPRI, said that ordinarily, firms in the paper industry would have to wait 3 years before seeing something in the general literature. Membership in the paper institute gives them immediate access to university research.

In addition, for firms with sophisticated research capabilities, early access to research ideas can lead to spin-off projects in their own labs that may lead to insights in totally unrelated areas.

Research at cooperative centers can raise productivity by helping firms to conserve materials and improve quality control. One example of a firm that realized substantial savings in time and money in this way is Bethlehem Steel Company. Computer graphics developed by RPI's CAD/CAM Center streamlined Bethlehem's steel rolling process, saving the firm costly machine runs and wasted materials. A research manager at Bethlehem Steel stated that the company would have "eventually" adapted this innovation, but the center made its introduction possible at an earlier time by helping to sell it within the firm.

<u>Improved education and training of scientists and engineers</u>

Cooperative centers can improve scientific and engineering education in several ways. Both students and industrial scientists can benefit from association with these centers, as can the curriculum in affected areas.

Educational improvement is explicitly recognized by most centers as a primary goal. A primary objective of some of the centers we visited was to upgrade the quality of scientists and engineers entering specific industrial fields. For example, when we interviewed the Associate Director of RPI's Center for Manufacturing, he characterized the center's primary objective:

> ...to attract the cream of students into the manufacturing area and to overcome the defect in the educational system at the secondary level. In high school, students are told that if they're bright, they should use their brains rather than their hands. Consequently, in college such students see themselves as managers/technocrats [instead of] getting oil on the end of their trousers."

Similarly, a research manager from Bethlehem Steel said that his firm participated in the CAD/CAM Center in order to hire graduates and, therefore, develop its human resources.

Students who are involved with cooperative center research get direct experience working with industry. They work on projects oriented to industrial needs. They interact closely with scientists and engineers while doing the research and during technical review sessions, where their research is critiqued by industry. They often have the opportunity to visit industrial research sites and to work as interns at firms. As a result of these experiences, students develop a much more realistic picture of industrial research. They also are trained to refine their research performance, communication, and presentation skills to accommodate industry. This substantially reduces the learning curve when making the transition from the university to the industrial laboratory.

Centers can offer a particularly significant opportunity to graduates of doctoral programs in science who face a tight job market. A postdoctoral appointment with a cooperative research center can make them more marketable. At the University of Delaware Catalysis Center, for example, a postdoctoral position is viewed as a "good stepping-stone to an industrial R&D position" for Ph.D. chemists who might otherwise find it difficult to make the transition to an industrial research environment.

A number of the centers we visited also provide opportunities for industrial scientists and engineers to keep in touch with state-of-the-art developments in their fields of interest. Many centers conduct technical sessions in which industrial researchers receive progress reports of work carried out at the center. These meetings, plus general interaction occasioned by the center's operations, increase industrial participants' ability to keep up with late developments through increased contacts with researchers from the university and other firms.

Cooperative centers can also have an effect on education which extends beyond their immediate circle of students and member firms. Several centers have attempted to advance the level of education in technological areas (such as catalysis) by disseminating curricula to other colleges and universities. This also occurs when doctoral graduates who have worked in a cooperative research setting go to teach at other colleges and universities.

WHAT MAKES COOPERATIVE RESEARCH CENTERS SUCCESSFUL

Cooperative centers often require some modification of both university and industry practices. Therefore, several important considerations must be addressed if these arrangements are to succeed. We found the following factors to be essential for the successful creation and operation of a center:

--A research focus conducive to multiple firm involvement.

--An adequate level of research expertise and equipment at the university to attract industrial interest.

--A strong leader with experience and understanding of both university and industry perspectives.

--Sufficient R&D sophistication in participating firms.

--A high level of commitment from both sectors.

--An organizational structure that promotes meaningful participation by university and industrial representatives.

All of these factors are interrelated. For example, the center's research focus will largely determine the expertise and equipment that are required and the kinds of involvement appropriate for industrial and academic participants.

A research focus conducive to multiple firm involvement

The first step in organizing a center is to identify an appropriate area of research that is of interest to a number of firms while not being of central importance to any particular one. Research that contributes to a firm's essential functions cannot be carried on in the open atmosphere of a cooperative center because firms will want to maintain proprietary control of results. However, the research must have some clear relevance to the firm's operations in order to warrant annual membership fees of $6,000 to $100,000. The research area must also have academic significance or the center will not attract faculty and student researchers, nor will it win academic approval as a legitimate part of the university's research program.

Within these broad limits, the centers we visited have developed varying levels of industrial specificity. Some focus on the needs of a particular industry (e.g., the Furniture Applications Center at North Carolina State and the paper industry at ESPRI). Others, like the Ohio State Welding Center and MIT's Polymer Processing Program, focus their research on an industrial

process that cuts across a number of different applications. Finally, some centers, like the Center of University of Massachusetts/Industry Research on Polymers (CUMIRP), focus on a research area such as polymer chemistry.

Focusing on the problems of a specific industry can be very helpful in providing a research capacity to disaggregated industries unable to sustain research on their own. However, it is probably the most difficult strategy to implement successfully because it depends upon the capacity of a number of competing firms to cooperate in formulating and performing research. This raises problems for the firms, not the least of which are concerns about possible antitrust suits. Also, the interfirm communication necessary for center success can be hindered by each firm's fear of losing competitive advantage. At ESPRI, for example, these problems have led to the center's promulgating strict rules that forbid discussion of pricing and markets.

Focus on a specific technology useful to several industries may alleviate antitrust problems by making it possible for centers to include only representatives of noncompeting firms. However, this approach often involves a problem-oriented, interdisciplinary research perspective which may hinder the capacity of faculty and students to publish their work in disciplinary journals.

One center which focused on a broadly applicable research area, the University of Massachusetts Center for Research on Polymers, has a membership of firms with sophisticated in-house research capacities. This is necessary for technology transfer to occur because substantial translation is usually required to make center products applicable to specific industry problems.

Adequate research expertise, equipment, and facilities

To successfully recruit firms and carry out a long-term research program, a cooperative research center must first establish a substantial base of research expertise and equipment. Assembling sufficient financial resources for this initial task can be difficult. In the centers we visited, initial seed funding was often needed to hire administrative staff, recruit qualified faculty, enlist enough firms to make a program viable, and, for some centers, to acquire state-of-the-art instrumentation.

All but one of the centers we examined used faculty to either conduct or oversee research. Representatives of several centers commented that recruiting qualified faculty was very difficult. Centers have a hard time competing with industrial demand for engineers and scientists. The chairman of a pulp and paper engineering department said that hiring faculty members is a challenge when industry can offer 50 percent to 100 percent

more than a university salary. "When undergraduates can command a salary of $22,000 and younger faculty can receive $25,000, a vast majority of Ph.D.'s go into industry...this problem is endemic to the whole engineering profession."

For research programs requiring state-of-the-art equipment, a source of funding that can underwrite the costs of developing an instrumentation base is critical. For example, the Catalysis Center at the University of Delaware needed $100,000 worth of instrumentation to begin its program. This and later instrumentation was eventually obtained by combining an award from a research foundation (UNIDEL) [1] with a contract from the U.S. Energy Research and Development Administration. At RPI, the university provided the funds needed to acquire equipment for its CAD/CAM Center because its administrators believed that neither Government nor industry money would be forthcoming for such a "risky" enterprise.

Several centers use equipment in associated university departments that was originally acquired through NSF grants. The Center for University of Massachusetts/Industry Research on Polymers, for example, uses the resources of the polymer science department and the Materials Research Laboratory, which were obtained with NSF's help.

Maintaining high quality equipment is an issue that some of the newer centers have not yet faced. Construction of laboratory equipment by students and support for equipment by NSF are two alternatives that have been used by older centers. Also member firms have donated used equipment and contributed equipment in lieu of membership fees. Firms also donate equipment to accustom students to its use. Sponsoring firms have donated over $3 million worth of software and computer equipment to RPI's CAD/CAM Center.

A strong leader

To begin a cooperative research center, one or more faculty members or administrators is required who is committed to the concept of cooperation with industry. These sponsors of the center must be willing to promote the idea to other faculty, university administrators, and representatives of prospective member firms. Successful promotion generally involves the development of center policies and programs that recognize the differing interests and constraints of academic and industrial decision-makers. Center champions are often people with both academic and industrial experience who are sensitive to the perspectives of

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[1]/UNIDEL is a Dupont-supported foundation dedicated to the University of Delaware.

both constituencies. For example, the industrial experience of the director of the MIT Polymer Processing Center was seen as a crucial component because of his ability to balance industrial interest in research applications with a strong commitment to innovative educational and research strategies at the center.

Industrial R&D sophistication

A firm's capacity to benefit from membership in a cooperative center is heavily influenced by the sophistication of its R&D capabilities. Firms which do not have substantial R&D capabilities are perceived by those that do as placing excessive demands on the limited resources of cooperative programs. The membership of such firms in cooperative centers creates the danger that university researchers may become increasingly involved in trouble-shooting and lose the fundamental focus of their research. This argument was expressed by the Executive Secretary of ESPRI, which discourages companies without research staffs from joining the institute.

> "...to profit from being a member of ESPRA, you have to have a sufficient research capability. In the past, some small companies have thought that ESPRI could serve as their research organization...It is ESPRI policy that firms can't come to the Institute and ask that it solve a problem for them. This would turn ESPRI into nothing but an errand boy."

He and others suggested that cooperative centers may be an inappropriate way for small firms to access the resources of the university and that an extension service might be more appropriate for such firms "when the university is the research organization for the industry."

Commitment to the center
by universities and industry

For both the university and supporting firms, a cooperative center requires adopting new methods of administering, funding, and conducting research. Participation in a center, therefore, requires flexibility by all parties. A high level of commitment among decisionmakers in both sectors, especially in the formative years, is critical if the flexibility required for success is to be developed and maintained.

Participation in a cooperative research center requires the university to be flexible in its publishing, patent, and licensing policies. The creation of a cooperative center has required changes in these policies at most of the universities we visited. Traditionally, the final products of university research appear as dissertations, journal articles, and monographs which are publicly available 2 to 5 years after a research project begins. Sponsoring firms typically wish to gain some special advantage in

obtaining access to results. Consequently, most cooperative centers delay distributing research results to the general public to give member firms first opportunity for commercialization. This guarantee of preferential access deviates from the university tradition that guarantees unfettered public access to university research. University administrators must therefore be strongly committed to cooperative centers to change these policies.

Similar levels of commitment are required of upper management in participating firms. To successfully use a center, firms must build internal structures to transfer information from the center to relevant divisions within the firm. They also require strong internal support within the firm because, in the absence of high level management support for a center, it is very unlikely that a middle manager would be willing to accept the risk and lack of control that participation in a cooperative center entails. This is shown by the experience of one administrator at RPI who said that corporate chiefs take a long-term view while "the middle manager has his neck on the block in regards to these programs." He added that:

> "...when one thinks of a firm the size of GM, it seems that it is contributing an insignificant amount of money to the program. However, the support of the center is actually coming out of the $200,000 research budget of one Bill Smith at GM, who must decide whether he wants to spend $50,000 or one-fourth of his research budget on a project to be performed by the Center for Manufacturing."

The adoption of research outcomes by firms is dependent on the extent to which firms participate in the program. Center directors can advise firms on how to make the best use of a program, but cannot ultimately influence the ways in which firms choose to participate. Although firms participated in several ways in the programs we visited, they all developed some internal mechanism to track the research performed at the cooperative center. They did this in two ways: through an industrial monitor, who is responsible for tracking research of interest to a firm, and through committees composed of representatives from different divisions within a firm who are responsible for developing lists of research proposals in technological areas that cut across a firm's operations.

Developing mechanisms to track the research performed at a cooperative center is not enough, however. For firms to get the most out of these programs, they must be active participants. This requires a strong commitment from top management. Time and money must be allocated to allow scientists and engineers from sponsoring firms to work closely with university researchers and to attend technical review sessions and industrial advisory board meetings.

Organizational structure

Appropriate organizational structures must be developed to allow interaction at each stage of the research process. We identified a number of such stages: formulating broad research themes, selecting specific research projects, overseeing the research, and transmitting research products to member firms.

Centers that conduct research aimed at addressing fundamental problems for sophisticated, high-technology firms tend to be structured in relatively traditional ways. They require industrial input primarily to ensure that their research is relevant to their clients' broad research needs. Centers that address less sophisticated firms, or attempt to address more applied and specific sponsor concerns, are more likely to develop organizational structures providing greater levels of industrial input and participation.

Failure to structure a center to adequately provide for industrial input into the research planning process can severely limit the capacity of a center to produce industrially useful research products. A dramatic example is the now defunct Furniture Institute at North Carolina State University. The major decisions governing the Institute's research agenda were made by a committee of university deans who had little contact with the needs or resources of the furniture industry. Thus research was dictated almost entirely by faculty interests. For example, developing robots to finish furniture was considered the most innovative project by the Institute but the cost of implementing it was too high for firms in the furniture industry.

THE FEDERAL GOVERNMENT'S ROLE

Federal involvement in creating and maintaining cooperative research centers has taken two major forms, providing planning grants through NSF's Industry-University Cooperative Research Center Program (IUCRC), and financing individual research projects and instrumentation at cooperative centers. In addition, the Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480), which authorizes the creation of "centers for industrial technology," was enacted but no funds were appropriated to implement it.

Providing planning grants and seed funding

The Federal Government has funded the creation and maintenance of 10 cooperative research centers through the NSF IUCRC program since its inception in 1973. The program typically offers two types of funding: 1-year planning grants to support initial planning and recruitment of industrial support, and 5-year, cost-sharing grants in which Government support is gradually phased out.

IUCRC initially provided 5-year grants to cooperative centers operated by MIT, North Carolina State University, and the MITRE Corporation to work with the polymer processing, furniture, and electric power industries, respectively. During the first 5 years of the experiment (1973-78), $2.4 million of NSF funds were matched by an estimated $3 million from 24 participating firms. Of the three original centers, only one--the Polymer Processing Center at MIT--still exists. It became self-sufficient in 1978 and its projected fiscal year 1982 budget was $800,000.

Between 1979 and 1981, four other centers were established: the Center for Computer Graphics at RPI, the Center for the University of Massachusetts/Industry Research on Polymers, the Center for Welding Research at Ohio State University, and the Center for Applied Polymers at Case Western Reserve University. In 1982, projected total Federal support for these four centers was $1.09 million. Industry would provide $3.2 million. In addition to industry's monetary support, centers have received a substantial amount of equipment and materials from industrial sponsors. The total value of equipment and materials contributed to all five currently operating programs has been estimated at more than $5.5 million. In 1982, NSF helped seed the creation of four other centers.

Beyond providing financial support for creating centers, NSF's involvement in the centers has produced a number of additional benefits. At RPI, for example, NSF support made it possible to establish a doctoral program in computer graphics. This program, in turn, has provided continuity to the university's research program. NSF program managers have also played important roles in centers. They have, at times, made valuable use of previous experience in mediating between university and industry participants. NSF's stature helped one center in its recruiting of industrial sponsors. A final advantage of NSF involvement has been the agency's requirement that each center be systematically evaluated. These evaluations have provided important data for planning new cooperative centers.

More recently, NSF has begun to work with agencies such as the Department of Energy and the Environmental Protection Agency in setting up cooperative centers. NSF program managers provide the expertise and then agencies provide the seed funding to create the centers. In the case of one center, NSF is funding the evaluation.

Financing individual research projects and instrumentation

The Federal Government has indirectly helped to sustain cooperative centers by funding grants to support individual research projects and research equipment. These grants have helped to reduce the initial costs and risks of starting up new centers;

they have provided longer-term funding where necessary for instrumentation, basic research, and education in centers; they have insured that knowledge and experience gained from the creation and operation of cooperative centers by NSF's IUCRC program is made accessible to those planning new centers; and they have provided long-term subsidies when a policy decision has been made that an industry or technology is of substantial national importance and the research target is highly risky or the industry in question cannot develop an adequate R&D capability on its own.

Passing Stevenson-Wydler Technology Innovation Act

The Congress laid the groundwork for a new way to support cooperative research centers by passing the Stevenson-Wydler Technology Innovation Act of 1980. The act authorizes the creation of "centers for industrial technology" by the Department of Commerce and the National Science Foundation. The objective of these centers is to enhance technological innovation by carrying out research supportive of technological and industrial innovation. The act also specifies a number of additional objectives for centers, including: assisting individuals and small businesses in generating and developing technological ideas supportive of industrial innovation and new business ventures; providing technical assistance and advisory services to industry (especially small business); and providing training and instruction in invention, entrepreneurship, and industrial innovation. No funding has been appropriated to create the centers authorized by this act.

CHAPTER 4

INDUSTRIAL EXTENSION SERVICES

Prior to development of the agricultural extension system, agriculture was composed mainly of thousands of small independent farmers and ranchers--a very fragmented industry--which had little capacity to sustain its own research and development. The success that Federal support for an integrated program of education, research, and technology transfer has had in agriculture provides a compelling model for possible Federal programs aimed at other fragmented, low technology industries.

INTRODUCTION

We base this chapter on our analysis of four programs that use the extension approach to address the needs of nonagricultural industries and firms. Our major objective was to determine the degree to which industrial extension has replicated the agricultural experience and the types of outcomes produced, what makes industrial extension successful, and the role played by the Federal Government. We briefly describe the extension approach as it was developed in the agricultural case, present our findings on the industrial extension programs that we visited, and discuss some issues that might affect future Federal initiatives in this area.

Agricultural extension

Agricultural extension is our oldest, most widely recognized system for transferring technology from universities to industry. In agriculture, extension has linked the research and educational facilities of the agricultural colleges with the farmer who is the user of the technology produced. The legislative structure of agricultural extension was based on a vision of the university as a community resource, responsive to the practical everyday needs of the community and committed to an educational and research agenda directly tied to those needs. Beginning with the Morrill Act of 1862, Federal support was provided to develop the educational base to teach agriculture and the mechanical arts through creating land grant colleges in each State. To increase agricultural productivity through research, the Congress funded the Hatch Act in 1887, which supports the development of State agricultural research stations. In 1914, the Congress passed the Smith-Lever Act to fund extension work, thus completing the integration of research, education, and technology transfer which constitutes the agricultural model of university-industry cooperation.

The county extension agent provides a crucial link in this university-community chain, helping the farmer understand and apply the results of university research, and keeping the university apprised of the utility of its products and the needs and concerns of the farmer. The personal interaction and community involvement of the extension agent has been an invaluable aid in transfering technology and information across the university-community boundary. When combined with the well-funded, decentralized research activity of the agricultural experiment stations, and the progressive education of new farmers at the agricultural colleges, the revolutionary changes wrought in agriculture during the last century become more comprehensible. Today, one acre of land produces four times the amount of corn that it did before extension. In 1920, one farmer fed 7 people; in 1970 a single farmer fed 50. The agricultural industry is currently a $200 billion a year business which annually exports $41 billion worth of goods. 1/ It is generally recognized that the Government's decision to sponsor the development and diffusion of technology for this industry where the individual farm was too small for any effective research was responsible for American agriculture's dramatic growth.

Applying the extension model to other industries

The dramatic achievements realized in the agricultural sector have led to considerable interest, past and present, in using the extension approach to serve other industries with inadequate access to new technology. Usually targeted are fragmented industries and small businesses that have not been able to establish their own research expertise or exploit existing technological capabilities to their full advantage. In many instances, firms within these sectors are viable but too small individually or disinclined to conduct research and development. As a result, innovation tends to lag. It is argued that, as in agriculture, the Government could use the extension approach to assist these firms in gaining access to technology and improve their productivity by linking them with university expertise.

HOW INDUSTRIAL EXTENSION WORKS

The industrial extension programs we examined are not full-blown replicas of the agricultural extension model. They all do not succeed, in different ways, in capturing the integrated system of education, research, and dissemination that exists in agriculture. Instead, they use elements of the agricultural model in carrying out their specific objectives. Usually they focus on the technology transfer feature of the extension model

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1/Stanford University, Institute for Communication Research, "Extending the Agricultural Extension Model," National Science Foundation (Contract number 75-SP 0265), pp. 11, 145, 147.

and do not have an active, ongoing research component. Instead, they attempt to help industry adapt and expand the use of existing technology. Also, unlike agricultural extension, which is fairly standard from one university to another, each industrial extension program has developed independently, so industrial extension represents approaches that vary substantially in their operation.

The programs we visited varied in the specific types of services they offered, the relationship of the program to the university, and the types of clientele they tended to address. All of the programs that we visited were directed at increasing the productivity of local businesses. However, the programs adopted many different strategies for achieving this goal. We classified the strategies in the following three categories: improved problem-solving capability, better access to new technology, and opportunities for continuing education.

Problem-solving

Three of the four extension programs that we visited devoted substantial time and resources to problem-solving for small businesses and entrepreneurs. We found two approaches to problem-solving, a clearinghouse approach, and a consulting approach.

In the clearinghouse approach, the center attempts to identify and deliver information and use human resources available in the university relevant to a client's stated need. For example, clients contact PENNTAP (the Pennsylvania Technical Assistance Program) extension agents who are located at each of 24 statewide continuing education offices. The client's problem or question is then transmitted to a technical extension expert located in a university department who, in turn, contacts the firm to further define the question. The technical extension agent taps his own expertise and that of other faculty members, as well as the university's information resources to provide information that will respond to the problem. When necessary, a follow-up visit is scheduled to interpret the information which has been gathered.

In the consulting approach, greater emphasis is placed on providing both technical and managerial assistance to improve a client's overall operations. Initial contact with a client is often followed by an on-site visit. The extension agent visits the client to develop a profile of the firm's operations and to identify technical and managerial problems. While the agent may tap university resources to solve a client's problems, he relies much more heavily on his own capacity to translate his particular experience and expertise into solutions. For example, the director of a regional office of the Georgia Tech Industrial Extension Service reported that extension agents find it necessary to seek assistance from personnel at the university or the Engineering Experiment Station in only 5 percent of the cases they encounter.

Technology transfer

One of the primary goals of all extension services is to improve their clients' access to new and improved technologies. We found that diversity among client firms can significantly impede this activity. Unlike agricultural extension, where client needs in a region are usually homogeneous because of common soil, crop, and climatic conditions, industrial extension typically serves a heterogenous client group which is not clearly delineated by technological boundaries. The types of information and assistance that these firms may need are likely to vary significantly.

If an industrial extension program attempts to serve its entire potential clientele, it will usually have to address a broad spectrum of technologies. This will substantially decrease the effectiveness of the technology transfer process because: the extension agent will have to be more of a generalist than a specialist; the program will be less able to sustain a relationship with an ongoing research program; and the effects of extension will be diffuse and not easily measured by indicators of technological innovation and productivity.

The extension programs we examined dealt with client heterogeneity in a number of different ways. One response, noted previously, was to accept this heterogeneity and to focus on problem-solving rather than technology transfer. Two other responses, however, retained a commitment to technology transfer activities. Some programs select specific technological areas that are relevant to the needs of a large number of local firms. At Georgia Tech, for example, an energy extension program carries out energy audits and helps clients to develop more efficient strategies for energy use. The other response is to focus on a small number of specific industries. North Carolina's furniture and textile extension programs, Georgia Tech's ongoing collaboration with the trade associations of the granite and poultry industries, and PENNTAP's active promotion of promising technologies in selected industries are all examples of this approach.

Continuing education

Providing continuing education to client staff is a part of every extension program's operations but the extent of these activities varies considerably among programs. All the programs that we visited operated occasional on-site workshops and demonstrations. Two programs--those at Texas A&M and North Carolina State--include ongoing, focused programs designed to upgrade training in new technologies for local industries. Continuing education is the principal activity of the Texas A&M Engineering Extension Service which provides on-site training courses to workers in public service industries (e.g., transportation and fire prevention). The North Carolina State Extension Service also includes an education component which provides short courses

in company workshops, packaged courses for the continuing education of engineers, and videotaped as well as televised courses.

Research

Substantial research efforts have been feasible in industrial extension programs only when the program can develop a clientele with interests that are sufficiently long-term and overlapping to warrant such an effort. This has been possible when a significant portion of the clientele consists of either the members of a single industry or the users of a specific technology. Narrowly focused research can be supported when (1) local firms in a particular industry are able to pool their resources through an industrial association or (2) external sources of support are available to push disseminating a particular technology.

Georgia Tech's extension program provides an example of the first situation. The poultry and granite industries used industrial associations to pool sufficient economic resources and political influence to sustain research efforts directed at their needs.

The second situation, support for disseminating technology, was found in Georgia Tech's Industrial Energy Extension Service in which funds from the U.S. Department of Energy made possible a modest research effort to develop and adapt energy technology to the needs of local businesses. Support was also found at the Texas Engineering Extension Service, which focuses its efforts primarily on training industrial workers in areas related to public service, such as road construction, law enforcement, fire protection, and energy production. This program has developed a research capacity in these areas by securing municipal and State government contracts. Research has been carried out on rodent control, odor and sewer systems, and the timing of traffic signals, using the academic research capacity of the university when appropriate.

TYPES OF OUTCOMES

Extension programs link universities to small businesses and fragmented industries that are limited in their ability to develop, evaluate, or adapt new technologies on their own. The outcomes of successful industrial extension efforts have almost always been small-scale; they provide access to information, do adaptive research to fit existing technologies to the needs and requirements of specific firms; provide short- and sometimes longer-term technical and managerial assistance; and sometimes help in promoting new technologies to local industries.

The primary outcome of extension programs is stimulating local and regional economic growth through a number of links that result from extension programs, including increased access to

technology and information, increased productivity, and increased relevance of university research and teaching to the practical needs of the community.

Increased access to technology and information

The most fundamental outcome of the extension approach is that it establishes a link between the university and that segment of industry which has the least ability to take advantage of new techniques and information. In all of the industrial extension programs examined, the increasing accessability of the university's resources and expertise to this segment of the industrial community was a significant outcome of the program, although significant economic impact was realized in only a very small number of cases. All of the programs provided university-based knowledge to their clients. While the individual approaches varied, from classroom teaching to on-site workshops and problem-solving, we found that the objective of transferring practical useful knowledge was accomplished.

Increased productivity

The extension concept is based upon the premise that potential users of new or existing technology may be unaware of that technology or its potential use to them. The extension agent is able to link the university source of information with the potential user. The agent must be sufficiently familiar with the university to find information suited to the user's needs while maintaining a sufficient appreciation of the situation to provide information that will be realistically useful to the agent. The agent has little leverage over the client's response to suggestions other than the demonstrated utility of the information provided--the agent must therefore square his or her assessment of the best solution to a problem with the client's perspective on risks and payoffs. Even when this succeeds, other factors, e.g., fear of new approaches, unpredictable market developments, or cash flow problems, may stand in the way of adopting suggested approaches. An example of the rate of translation of extension suggestions into realized changes was given by an extension agent at Georgia Tech. He reported that of the 136 clients he contacted between 1973 and 1975, 59 requested and received services, 22 took action on these services, and 14 of the 32 had achieved visible benefits as of January 1980. We found some additional evidence of the effect of industrial extension programs:

--PENNTAP asks each of its clients to estimate the value of changes resulting from contact with the extension service. The total investment in PENNTAP during the period from 1972-81 was about $3.2 million. Using data based on a 40 percent to 50 percent response

rate, PENNTAP reported that it had produced benefits totalling approximately $52 million during this period, resulting in a benefit/cost ratio of 16.2:1.

--In an evaluation of the Georgia Tech industrial extension program, Arthur D. Little, Inc., examined successful interactions between the extension service and six client firms and found that 300 jobs had been created or saved by the extension service, resulting in a benefit/cost ratio of 22:1.

Increased university relevance

The extension approach has operated in agriculture as a two-way conduit, carrying problems from the farms to the laboratory and research outcomes from the laboratory to the user. As a result, both the educational and research functions of the university are continually influenced by the practical concerns of the surrounding community. This link of education, practice, and research increases the relevance of the educational process and pools the resources and talents of university and industry personnel.

This feature of the agricultural extension approach can be applied to other fields. It is not a quick-fix approach but a long-term effort to institutionalize a better relationship between the two sectors.

We found that industrial extension programs generally have not come close to the agricultural model. Industrial extension has generally been a very small-scale effort located on the periphery of university activities. Of the four programs that we visited, only one, the North Carolina State program, has achieved a position in the university comparable to agricultural extension in agriculture schools. Extension activities at North Carolina State are given equal status with teaching and research; they are administered by a vice chancellor of extension and extension agents are given comparable status to other faculty in many university departments.

WHAT MAKES INDUSTRIAL EXTENSION SUCCESSFUL

Industrial extension programs can provide an important link between the knowledge and expertise residing in a university and the technological needs and problems of small- and medium-sized businesses that lack the financial and technical capacity to monitor and adapt technological developments. Creating an effective link depends upon a number of factors that are difficult to control. We found four factors that contribute to successful industrial extension: integrating extension into the university's mission, maintaining adequate funding, adopting an appropriate balance between promoting new technology and problem solving, and resolving conflicting objectives of the two sectors.

Integrating extension

The success of agricultural extension has been attributed to its acceptance by educators, researchers, and extension agents as an integral part of the university's mission. This acceptance has developed because the land grant college system was developed with such integration in mind. Agricultural colleges were founded to teach; agricultural research stations were created to develop technology, and finally, extension was introduced to deliver this knowledge to the farming community.

This integrated approach generally does not exist with industrial extension, where programs have generally been grafted onto pre-existing ones. Their degree of connection to academic life varies but extension rarely has been placed on an equal footing with education and research commitments. In most cases, firm ties have not been made between the research and education objectives of the university and efforts to meet the needs of extension clients. At Georgia Tech's Industrial Extension Division, for example, where much of the extension work is done through dispersed field offices, integrating extension into the ongoing life of the university is minimal. Extension agents have little contact with the university and the primary contribution that the university makes to the extension effort is the credibility of its name.

The failure to integrate extension into the life of the university creates situations in which support for extension is extremely dependent upon the university's commitment to public service. If this commitment decreases or changes in focus, university support for extension may become increasingly tentative, and the relationship between extension and mainstream university activity may weaken.

Some extension efforts are more closely linked with the educational or research activities of the university. In the PENNTAP program, for example, extension specialists are located in university departments. This increases their contact and involvement with university life and keeps them aware of new developments in their fields of expertise. From an organizational point of view, North Carolina State is probably the best example of a university that has successfully integrated extension into its research and educational programs. In some of its schools--such as furniture, textiles, engineering, and forest resources--links between extension and the research and educational function of the institution are nearly as strong as those found in agriculture. Strong commitment at a high administrative level and inclusion of extension in the reward system of the university has strengthened those bonds.

Maintaining adequate funding

Because extension is usually aimed at a clientele that is unable to pay for services provided, extension programs need consistent and large-scale funding. In the case of agriculture, support for extension comes primarily from the Federal Government, for several reasons. First, agriculture's public funding began at a time when over half of the U.S. workforce was engaged in agriculture. Second, the availability of food was an issue central to the Nation's well-being; supporting agriculture was an easily recognizable public need. Third, the fragmentation of agriculture made it clear that farmers could not easily support their own R&D; external support was required. These factors, coupled with the farmers' ability to organize and lobby for support on a national level, help to explain Federal willingness to establish and support a full-blown research and extension establishment for agriculture, as opposed to other fragmented industries.

Attempts to secure consistent Federal support for nonagricultural industrial extension have been largely unsuccessful. No single industry or sector has been able to make the compelling case for Federal support that agriculture made.

All of the industrial extension programs that we examined derived their initial funding support from State governments. Two basic strategies were used in obtaining and then retaining this support over the years. The first was to direct the program's services at a homogenous client base important to the States' economic development. In many cases these clients could lobby effectively as a group for continuing State support. This approach has been successful for North Carolina State's program. The second strategy was to link industrial extension to the education and research work of the university, or to the State government's economic development work, to assure support. This approach has been used at North Carolina State, Georgia Tech, and in the PENNTAP program.

State funding, however, usually is not sufficient to allow any of the programs to respond adequately to client needs. The engineering staff necessary to support adequately an extension program for manufacturing industries is very costly. Salaries of extension agents at Georgia Tech, for example, were $25,000 to $30,000 a year. When overhead is included, the cost of supporting a single extension agent ranged from $33,000 to $50,000 a year. This expense is exacerbated by the fact that industrial extension requires a sizable staff to provide its many clients with a wide range of services. Industrial extension programs generally have inadequate extension agent-to-client ratios. For example, the Savannah office of Georgia Tech's industrial extension program has only two generalist extension agents servicing about 450 companies.

To obtain adequate, sustained financial support, some programs have tailored their services to a client base capable of paying for it, rather than serving the smallest or neediest clients. All four of the programs we visited began with either State support or a mixture of State and Federal support. Two of these--North Carolina State and Texas A&M--have grown into multimillion dollar programs by obtaining industrial support for their services. Texas A&M retained some of its ability to serve needier clients by directing extension services to the members of an industry association who could not support such a program individually but collectively. Georgia's and Pennsylvania's programs, by contrast, are still funded primarily by the public sector, and remain budgeted at about $500,000 each.

Balancing approaches

Extension program managers must balance technology pull and push approaches to provide their clients with technology appropriate to their particular situations. The technology pull approach serves clients by developing technologies in response to needs. The technology push approach is essentially the reverse; the technologies are developed first and then clients are sought who will use them. Initially, the agricultural effort was a push approach, developing new techniques and then presenting them to farmers. Later, as farmers became more sophisticated, extension became a pull approach; technology was developed in response to a specific client need.

Total reliance on technology pull implies a willingness on the part of the university to rely completely on client assessments of their own needs. While this would seem to be maximally responsive to client desires, it could easily lead to a situation where the extension staff is made up completely of generalists and where efforts are extremely diffused and largely unrelated to other university functions. On the other hand, if a university concentrates too heavily on the push approach, it could easily be caught in the trap of expending valuable resources on developing inventions that are of no interest to potential clients.

The industrial programs we reviewed varied in the degree to which they concentrated on technology pull versus push. At Georgia Tech, the former is emphasized. Georgia Tech's extension agents operate by responding to the problems that clients bring to them. In PENNTAP, there is more of an emphasis on the latter. PENNTAP agents attempt to identify new techniques that might have relevance to local industry and actively seek out clients willing to experiment with them. Texas A&M also concentrates on technology push. By training employees in specifically designated fields, this program pushes new technology by updating workers in target industries on new developments. North Carolina State combines both approaches through its assignment of extension agents. Some employ the pull approach; they are given responsibility for all requests emanating from a particular

region of the State. Others employ the push approach: they disseminate new ideas that arise from specific academic fields or that are useful in specific industries.

Resolving conflicting objectives

Industrial extension is not a traditional university activity, nor is it a natural product of such an activity. The extension workforce does not, therefore, carry with it a preconceived generally accepted definition of their objectives. Potential clients, by the same token, do not have a generally agreed-upon notion of what the program's objectives ought to be. To avoid confusion and promote efficient use of resources, a program's assistance must be directed toward a clearly defined end. Two controlling objectives for extension programs are possible. They may be directed at stimulating growth and productivity in well-established firms, or they may concentrate on increasing economic equity among firms.

Programs that are intended primarily to accelerate growth and increase productivity produce benefits mainly for firms that are financially able to take the risks associated with technological innovation. Such firms generally require fewer specialized services to benefit from extension. One indirect by-product of this assistance is that small, weak, unchanging competitors of assisted firms may be driven out of business.

Programs that are directed at economic equity work with small, weak firms to enhance their competitive ability. Such efforts require considerable expense. The client firms are generally technologically unsophisticated, cannot define their needs, do not have the resources or abilities to adopt technologies on their own, and are highly resistant to change. In such circumstances the university's traditional academic resources are not useful. Instead, entirely new administrative and delivery structures must be set up to mediate between the university and client, skilled extension agents must be hired, and field offices maintained. This approach is used at Georgia Tech, and consequently there is constant concern about program funding. Agents must devote much of their time to contract work and economic development activities to secure sufficient funds to keep the program afloat. The choice of an equity orientation obviously requires a strong commitment of the university to public service.

THE FEDERAL GOVERNMENT'S ROLE

Federal funding for industrial extension has been sporadic and short-term. Limited support has been provided through two mechanisms, the short-lived State Technical Services program (STS), and Federal mission agency project funding at existing industrial extension programs.

The main purpose of the STS program, which went from 1965 to 1968, was to promote industrial modernization and economic growth to improve the competitive position of American businesses and industries in world markets. The Federal Government and the States shared the cost of setting up the industrial extension services.

The program failed to produce results resembling those achieved in agricultural extension. This failure has been attributed primarily to the fact that Federal funding was too low and too short-lived to produce the structures needed to ensure success. The total Federal expenditure of $20 million spread out among 50 States over 3 years was not adequate to hire and train the staff, particularly field agents, who could provide the consistent follow-through that is essential to ensure any extension program's success.

The Federal Government has funded many projects at existing industrial extension programs that are related to specific Federal missions. They can be grouped into five major categories.

The first group (e.g., Georgia Tech's Energy Extension Service) promotes disseminating a specific technology deemed crucial to the public good. A second group facilitates interpreting and/or adhering to Government regulations. For example, two extension agents at Georgia Tech get funding from the Occupational Safety and Health Administration to identify and help correct occupational safety and health problems. Projects in a third category were designed to stimulate regional economic development. For example, some industrial extension programs providing technical assistance services receive funding from the Economic Development Administration. Small Business Administration programs make up a fourth group. For example, in 1977, SBA funded eight small business development centers at universities to provide assistance to local small and medium-sized universities, and to help universities develop educational and research programs oriented to the needs of local small businesses. Finally, there are several projects that support the well-being of industries deemed crucial to public welfare. One example is the National Oceanographic and Atmospheric Administration's Sea Grant Program, which is designed to assist the maritime industry.

CHAPTER 5

SUMMARY

From this study, we have found substantial evidence that deliberately planned long-term institutional cooperation between universities and industry can strengthen links that enhance technological innovation. Each arrangement (the research park, the cooperative research center, and the industrial extension) affects the links and outcomes in different ways and to varying degrees; and hence, may be more or less suited to achieving particular policy objectives. However, the successful creation and continuing viability of each arrangement depends upon certain critical factors, some of which are general and others specific to each type of institutional arrangement.

The Federal Government has been involved in a variety of ways in fostering cooperative arrangements between the two sectors. In this chapter we summarize our findings with respect to each form of collaboration we examined (see table 3) and present conclusions that are germane to consideration of any new or revised Federal initiatives intended to foster university-industry collaboration.

OUTCOMES ACHIEVED BY UNIVERSITY-INDUSTRY COLLABORATION

It is generally recognized that university-industry cooperative arrangements provide opportunities for increased communication between scientists and engineers in the two sectors. We found that the nature and intensity of communication varies greatly among the different cooperative arrangements, ranging from mutual intellectual stimulation of scientists and engineers in both sectors to more service-oriented technological assistance by university transfer agents for fragmented low-technology industries. We also found that university-industry cooperation may contribute to industrial innovation by

--facilitating early recognition of significant breakthroughs in basic research areas which make new products and processes possible;

--increasing the rate at which scientific and technical knowledge and understanding are adapted by industry;

--increasing the availability of sophisticated facilities, equipment, and expertise to scientists and engineers in industry and universities;

--orienting university research more toward industrial needs and opportunities (e.g., interdisciplinary research);

- --increasing the quality of graduate training of industrial scientists and engineers;

- --increasing the rate of founding new businesses that exploit science and technological developments, and improving their capacity to survive;

- --increasing the capacity of backward and/or financially constrained businesses or industries to take advantage of scientific and technical developments.

The nature of the contributions to innovation most likely to be realized depends on the type of cooperative arrangement.

Of the three types of collaboration we have considered, the most dramatic contribution to innovation appears to be made by research parks, which enhance university-industry interaction at the frontiers of science and the leading edge of industrial technology. Interaction between the two sectors is enhanced in a variety of ways, such as providing industrial employment of faculty consultants, adjunct faculty appointments for industrial research specialists, sharing of laboratory facilities, part-time employment of graduate students, special graduate courses for industrial employees, and joint research projects and seminars.

The most intense interaction we observed occurred at the Stanford Research Park, where we found that the philosophy of industrial collaboration has been fully integrated into the academic mission of the university. A major consequence is that communication and rapport between academic and industrial sectors have reached a higher level than in any other research park we reviewed. This interaction increases the flow of information and ideas that affect the research agendas of both sectors and increases academic sensitivity to the possible commercial utility of emerging ideas and research findings. Another measure of success of the Stanford Research Park is its effect on regional economic development. Many technology-intensive firms, both large and small, have been attracted to the Silicon Valley region surrounding the park to take advantage of the university's center of excellence and the industrial cooperative education program.

The Stanford success can be attributed in large measure to an extremely favorable set of circumstances that prevailed for more than 2 decades during the creation and early development of the research park. Stanford owned many acres of undeveloped land that was available for long-term leases but could not be sold; the Federal Government was rapidly expanding its funding of basic and applied research at universities; and Stanford had a leader with exceptional vision dedicated to the research park concept who was greatly respected by academic, industrial, and Government sectors. Although it is unlikely that such an ideal situation

will emerge again, we believe that if all of the critical factors summarized on the next two pages are realized, it is possible for other research parks to emulate many of the successful attributes demonstrated at Stanford. This view is supported by evidence obtained from our review of other research parks.

Cooperative research centers create new partnerships by bringing universities and industry together in jointly planned research aimed at accelerating the advance and commercial application of technology. The research agenda of a center is usually designed to fill gaps in science, related to technology, which no company would be likely to support alone in its own laboratories, e.g., to improve scientific understanding of empirically developed processes and techniques. Although both basic and applied research may be included, the research tends to be more interdisciplinary and application-oriented than research performed in academic departments concerned with individual scientific disciplines. Faculty and students participating in the cooperative research centers gain awareness of industrial perspectives that affect the orientation of academic programs. Universities involved in such centers also make substantial contributions to improving the initial and continuing education of industrial scientists and engineers.

Industrial extension is singular in providing assistance to new, low-technology, and fragmented industries. Industrial extension services may attract new businesses to a region, create an information resource about the local economy which many be used by local development organizations, and contribute to the productivity and economic viability of existing local businesses and industries. In most cases, industrial extension has not had much effect on university research agendas.

CONDITIONS THAT FOSTER SUCCESSFUL COLLABORATIVE ARRANGEMENTS

We found that two issues are associated with implementing any university-industry arrangement--those that are generic to any form of university-industry collaboration and those specific to a particular type of collaboration. Generic issues include the need to reconcile the different objectives, values, attitudes, reward structures, and research agendas of the two sectors; and locate a source of continuing financial support. An example of a specific issue is the requirement that university and industry participants in a cooperative research center must agree upon a mutually acceptable research agenda. Critical factors essential to resolve the generic issues for successful collaborative arrangements of any type include

--commitment by both faculty and administrators at a university to the concept of orienting some portion of university research and expertise toward industrial needs and opportunities;

--commitment by participating firms to explore and utilize the strengths of the university while simultaneously honoring university objectives;

--flexibility in the university to allow policies and organizational developments for interaction with industry that are responsive to industrial objectives but do not compromise the academic mission of the university;

--a strong leader highly respected by both the academic and industrial communities to establish and maintain the partnership;

--matching the physical and human resources, needs, and interests of both university and industrial partners; and

--sustained sources of funding.

Each specific type of collaborative arrangement draws upon different strengths and resources of university and industrial participants and is not likely to succeed unless universities and firms possessing the relevant strengths and mutual interests are involved.

Research parks work best at first-tier research universities where a significant proportion of administrators and faculty favor interaction with industry. Industrial participants most likely to benefit from this arrangement are high-technology firms that depend strongly on technological innovation for their success.

Cooperative research centers require a university with strong departments in areas relevant to the focus of a center. Industrial participation is most successful with medium to large-sized firms which have their own research and development capacities adequate to translate the research results into commercial technological applications.

Industrial extension services are best performed by a university with a strong commitment to community service and a technology focus to assist local, fragmented industrial clients.

GOVERNMENT ROLES IN UNIVERSITY-INDUSTRY COLLABORATION

Federal and State governments have played both direct and indirect roles in creating and sustaining different university-industry arrangements. These roles can be characterized generally as improving the climate for university-industry interaction by supporting research in both sectors, catalyzing the creation of specific arrangements through seed funding, providing long-term financial support for selected cooperative arrangements, and providing mission-related project funding to existing arrangements.

In research parks, the Federal role has been predominantly indirect by fostering a climate in which industrial firms are more likely to find proximity to a university attractive. Federal support for basic and applied research at universities has been used by some universities to build research excellence at the frontiers of industrial technological developments. Continuing Federal support for such research makes proximity to the universities valuable to high-technology firms because the research performed at the university augments the research and development activities of the firms in the park.

In addition to funding university research, the Federal Government has provided support to research parks by awarding contracts to spin-off firms, locating Government research operations in research parks, and donating land to the host university.

In cooperative research centers, the Federal Government has played a convening and catalytic role by providing seed money to help underwrite experiments with the arrangement. The intent is to help develop new research areas that are of mutual interest to universities and industry, but that are either too peripheral or risky to be sponsored by any single firm. The National Science Foundation's Industry-University Cooperative Research Center program is the primary example of this kind of Federal role. This program has provided seed funding and co-sponsorship for eight cooperative research centers since 1973. The Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480) authorized the creation of "centers of industrial technology" by the Department of Commerce and the National Science Foundation. To date, however, the Congress has not appropriated any funds to implement the Act.

Unlike the long-term, comprehensive support for an integrated program of education, research, and technology transfer that the Federal Government provides for agricultural extension, the Federal role in industrial extension has been limited to supporting specific mission-related technology

transfer projects (e.g., economic development, energy conservation) at universities with existing extension programs. Except for the short-lived State Technical Services program, most of the direct funding for industrial extension has come from State governments.

CONCLUSIONS

The Federal Government has played a significant role in creating and sustaining each type of institutional arrangement by providing

--support of basic and applied research at universities to build excellence in fields of science at the frontiers of emerging industrial technology,

--contract support for R&D at new spin-off high technology firms,

--seed money to stimulate creation of cooperative R&D centers plus continuing project support by grants and contracts, and

--both seed money and continued funding of extension services.

Financial support alone will not assure success of any of the forms of institutional cooperation. Both the generic and specific critical factors for each type of arrangement must be addressed to assure

--well defined objectives and expected outcomes of the collaboration;

--matching the resources, needs, and interests of both university and industrial partners; and

--institutional commitments and leadership capable of reconciling the generic differences between universities and industrial partners without incursions on the independence of either.

Federal policy initiatives intended to foster closer links between universities and industry should be designed to

--relate policy objectives to expected outcomes,

--use the most appropriate type of collaborative arrangement, and

--make any targeted financial support contingent upon evidence that the partners proposing the institutional arrangement are prepared to address the generic differences between the two sectors and that the critical factors essential to reconciling them are in place or realizable.

Table 3. Characteristics of Three Types of University-Industry Arrangements

Type of Arrangement	Modes of Interaction	Major Outcome	Critical Factors	Federal Involvement
Research Parks	Research cooperation on frontiers of science and technology Informal interaction Increased sharing of research facilities and participation in consulting, seminars, and continuing education	Increased communication and intellectual stimulation of both sectors Early recognition of commercializable research and acceleration of innovation process Improved training of industrial scientists and engineers Enhanced regional and local economic growth	University commitment to industrial interaction Good fit between university and industrial strengths and research orientations Reconciliation of research objectives, values, and reward structures Strong leadership in academic institution	Funding of university research Contract support for spin-off firms
Cooperative Research Centers	Joint research planning and execution Faculty and student participation in research centers	Improved coordination of university and industrial research Research outcomes oriented to industrial needs and unlikely to be done otherwise Improved education and training for students preparing for industrial careers	Research focus conducive to multiple firm involvement Research expertise and equipment at the university Strong leadership and commitment of all participants Sophisticated R&D in participating firms Active participation by both sectors	Planning grants and seed funding Project and instrumentation support Legislative authorization of Federal assistance for new centers
Industrial Extension Services	Information transfer and consulting by university transfer agents Workshops, classes	Increased access to technology by fragmented industry Increased relevance of university to community Enhanced regional economic development	University commitment to extension External funding Technological focus	Sporadic project support Cost-sharing with State governments

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